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Overview of Kinematic Variables in Top Production

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OVERVIEW OF KINEMATIC VARIABLES IN TOP PRODUCTION

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A selection of simple kinematic variables chosen to be sensitive to different aspects of $t\bar{t}$ production in $W + \geq 3$ jets events are studied. Monte Carlo comparisons are made between different top generators (Herwig, Pythia, and Isajet) and a QCD background generator (VECBOS). Finally Monte Carlo predictions with the $t\bar{t}$ fraction constrained by the SVX b-tagging rate and measured top mass are compared with 110 pb^{-1} of CDF data. We conclude that the CDF data is consistent with standard model predictions using the studied generators.

1 Preliminaries

1.1 Data Set Selection

The data cuts are similar to those of the standard CDF counting experiment.¹ The important features are the following:

- Leptons: $P_T > 20 \text{ GeV}$. This is both the charged lepton and the neutrino (the missing E_T from the calorimetry corrected for muons).
- Jets: They are ordered in transverse energy E_T . The first three jets are required to have $E_T > 15 \text{ GeV}$ and detector $|\eta| < 2$.
- 4th jet: Sometimes an additional requirement of $E_T(\text{jet4}) > 8 \text{ GeV}$.
- SVX b-tag: The b-tagged data set requires a jet with a displaced vertex identified by the silicon vertex detector.

1.2 Monte Carlo Generators

All Monte Carlo events are put through complete detector simulation. VECBOS is used to generate QCD $W + \geq 3$ jets background events. The primary $t\bar{t}$ generator is Herwig 5.6, with comparisons made to Pythia 5.7 and Isajet 7.06. All three $t\bar{t}$ generators start with a hard scatter and make LLA corrections via parton showers.² Herwig uses coherent parton showers, cluster hadronization, and an underlying event based on data. Pythia has string hadronization and an underlying event based on multiple parton scattering. Isajet uses incoherent parton showers.

2 Kinematic Overview Plots

For simplicity, the mean and rms of each variable are used to characterize both the variables and the different Monte Carlo generators. The variables

include the E_T of the jets (ordered in E_T), missing E_T (neutrino), P_T of the muon or electron, H (sum of all the E_T in the event), Mass $W + 4$ Jets (the invariant mass of the W and 4 highest E_T jets), $|\eta|_{\max}$ (maximum $|\eta|$ of the 3 highest E_T jets), Aplanarity (fractional $\sum P^2$ perpendicular to the plane with the maximum $\sum P^2$).

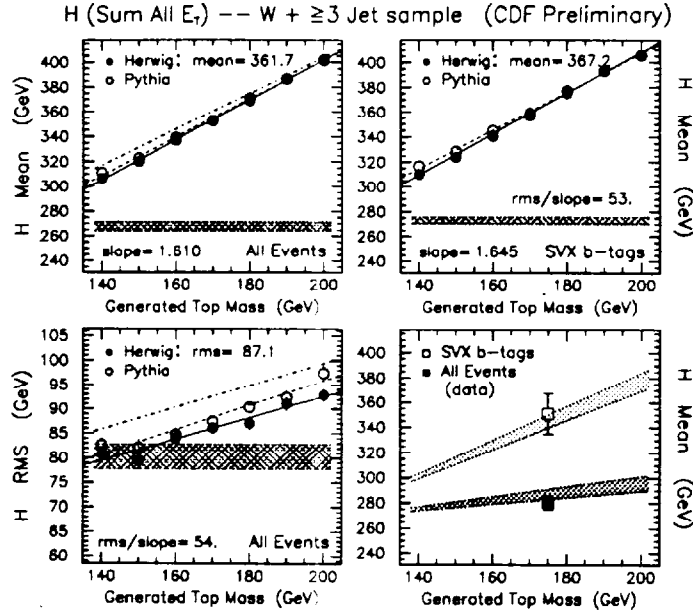


Figure 1: Overview plots for the H variable (sum all E_T). The mean or rms is plotted against the generated top mass for the indicated data set. The solid points and lines are Herwig, the open circles and dashed line are Pythia, and the dot-dashed lines are Isajet. The hatched horizontal bands are the limits of VECBOS with two different q^2 scales. The plot on the lower right compares the data means with Monte Carlo bands constrained by the measured $t\bar{t}$ fraction.

Figure 1, the overview plot for the variable H , is typical. The two plots on the left are for the ≥ 3 jets data set which is about 20% top; the plot on the upper right is for the SVX b-tagged data set which is about 75% top. Several features should be noted. First, the mean and RMS printed on the plots are for the fit to Herwig evaluated at 175 GeV. Secondly, the top generators exhibit consistency and are to a good approximation linear in generated top mass. Third, the difference between the tagged and untagged data sets is small. Fourth, one can estimate how well a variable differentiates between $t\bar{t}$ events

and VECBOS events at a given top mass by noticing the difference between the $t\bar{t}$ mean and the VECBOS mean relative to the rms.

Another point of interest is that variables that have a small rms and a large slope are more sensitive to top mass. The smaller the value of 'rms/slope,' the better the variable is for measuring top mass. In this study, the H variable and the Mass of W + 4 Jets have the smallest values of 'rms/slope.' In general the higher energy jets are more sensitive to top mass and the lower energy jets are better at discriminating between $t\bar{t}$ and VECBOS. Using the lower right plot in figure 1, it can be estimated from the H variable that the top mass is about 180 GeV with a 20 GeV uncertainty. Note that the statistical accuracy of the mean is degraded by the long tails of the H distribution; using a fit instead of the mean would significantly reduce the uncertainty in the top mass by minimizing the effect of these tails.

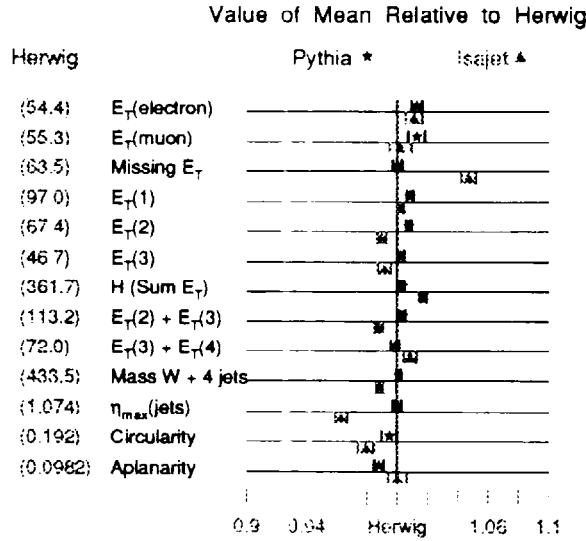


Figure 2: Fractional deviation of Pythia and Isajet means from Herwig. The stars are Pythia and the triangles are Isajet. The Herwig mean is printed on the left.

Figure 2 shows the fractional differences of the means of Pythia and Isajet relative to Herwig for our set of variables. The agreement with Pythia is quite good. Isajet shows more variation, much of which is consistent with it having more gluon radiation. Another observation from this study is that the b-tagged events in general have smaller $|\eta|_{\text{max}}(\text{jets})$ which is consistent with a tagging bias towards more central events and slightly higher E_T jets.

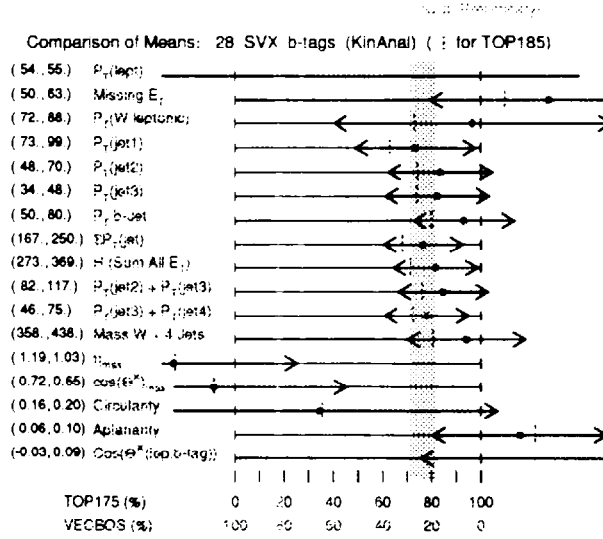


Figure 3: The data means relative to VECBOS and Herwig Top 175 for the SVX b-tagged sample. The left-hand ticks on each line correspond to the VECBOS means and the right-hand ticks to the Herwig means (actual values are printed on the left). The vertical band shows the predicted $t\bar{t}$ fraction. The solid points and arrows show the data means and their statistical uncertainties relative to VECBOS and Herwig.

The SVX b-tagged sample in our data is 28 events. It is expected to be about 75% $t\bar{t}$ from the SVX tagging rate and the estimated backgrounds. Figure 3 compares the means of the data relative to the means of VECBOS and Herwig Top 175. The shaded vertical band corresponds to the expected $t\bar{t}$ fraction and its uncertainty. The points corresponding to the data means are quite consistent with the band.

3 Kinematic Distribution Figures.

These figures show the actual distributions of the data for a variable. The untagged data set for these plots requires a 4th jet with $E_T > 8$ GeV and contains about 35% $t\bar{t}$. There are four plots: two standard differential plots and two integral significance plots. In all plots only the shape of the data is compared with the Monte Carlo predictions. The widths of the bands in the integral significance plots are due to the uncertainty in the $t\bar{t}$ fraction and the q^2 scale for VECBOS. Often an analysis gives the significance of the fraction of events above a cut; these integral plots show the significance of the number

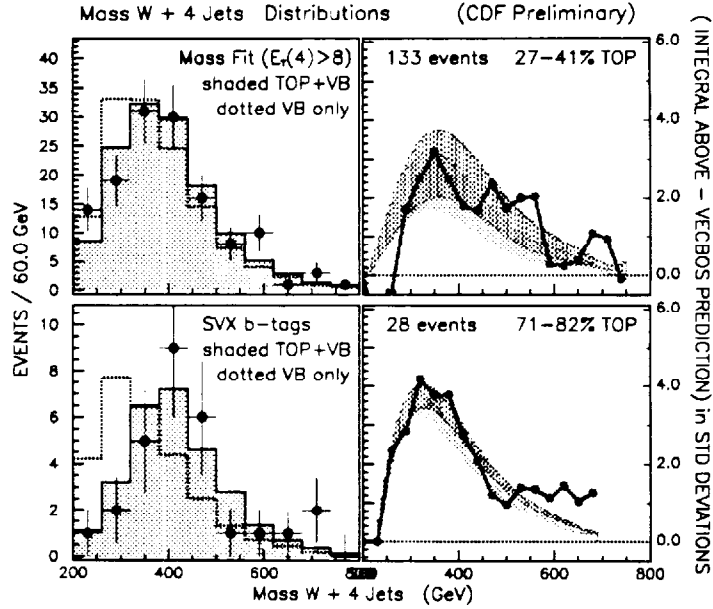


Figure 4: Distributions for Mass W + 4 Jets. The solid points are the data. On the left are standard differential plots: the dashed histogram is pure VECBOS and the shaded area is the expected mixture of VECBOS and Top 175. The plots on the right are the deviation of the data integral from the VECBOS prediction in units of expected statistical uncertainty: the shaded band is the prediction for VECBOS and Top 175 and the striped band is for VECBOS and Top 185.

of events above any cut. Figure 4 shows the plots for the variable Mass W + 4 Jets. The agreement is reasonable and there is no indication of an anomalous variation from predictions at high $t\bar{t}$ invariant mass.

4 Conclusions

Using a variety of variables, a comparison was made between different $t\bar{t}$ generators and reasonable agreement was seen. The sensitivity of the variables to different aspects of $t\bar{t}$ production was also examined. Finally the data was shown to be in agreement with the predictions of Herwig and VECBOS constrained by the measured top mass and $t\bar{t}$ fraction.

1. CDF Collaboration, F. Abe *et al.*, *Phys. Rev. Lett.* **74**, 2626 (1995).
2. I. Knowles and S. Protopopescu, in *Argonne Accel.Phys.*, (1993), p.651.